Von Der Lippe

Cost of Moving Earth

Civil Engineering

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COST OF MOVING EARTH

BY

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THESIS FOR DEGREE OF BACHELOR OF SCIENCE
IN CIVIL ENGINEERING

COLLEGE OF ENGINEERING
UNIVERSITY OF ILLINOIS
PRESENTED JUNE 1902

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UNIVERSITY OF ILLINOIS

May 30 1902

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Ernest Carl Friedrich Von der Lippe

ENTITLED Cost of Moving Earth

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Civil Engineering

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HEAD OF DEPARTMENT OF Civil Engineering

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Cost of Moving Earth

It is the object of this paper to investigate the cost of moving earth in the construction of wagon roads, railroads, irrigation canals etc. There is not much literature on this subject and most of it deals with antiquate methods. Among the articles frequently quoted are two by Ellwood Morris having the titles: "On the Cost of Excavations by means of Scrapers or Scoops, and "On the Cost of Embankments of Earth when made with Carts", which appeared in the Journal of Franklin Institute, 3d Series, Vol. 2, 1841. Another article frequently referred to is that in Trautwine's Engineer's Pocket-Book entitled, "Cost of Earthwork".

Before discussing modern practice the writer will consider the results of each of the two authorities referred to. Morris's articles have an important place in engineering literature, even at the present time; but are so inaccessible that the writer presents a complete copy of the first and the most important parts of the second article.

Part I, Morris's Results.

"On the Cost of Excavating Earth, by means of Scrapers or Scoops."*

By Ellwood Morris, Civil Engineer.

[Complete Copy]

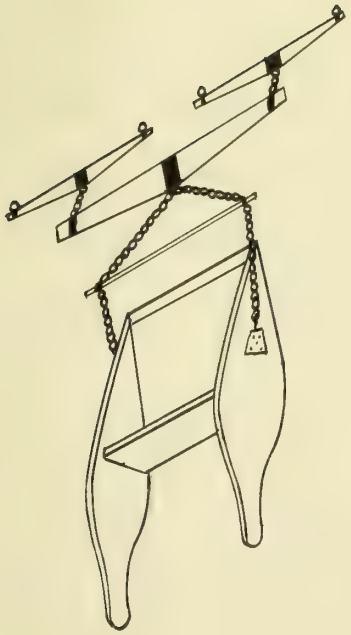
"Of all machines known to the American Engineer, and used upon our public works for the excavation of earth and its removal to short distances, the scraper or scoop is within the proper sphere of influence, by far the most economical.

"This instrument is particulary well known to Canal Contractors, is much used by them in earth cutting and is most frequently employed in excavating the trunks of canals, where they are so laid out that the cutting makes the bank, or nearly so; but the scoop may be used with success in all excavations of earth where the slope does not exceed 1½ to 1, if the material to be taken out yields readily to the plow and is not required to be moved more than 100 feet, nor to a vertical height exceeding 15 feet. There are doubtless instances where both of these limits may be surpassed, and the use of the scoop still be highly economical: but such cases are not general, and the practical scope of the utility of scoops may be regarded as confined to the excavation of canal trunks, for which purpose it is most admirable adopted.

* Journal of Franklin Institute, Vol. 2, page 26. Philadelphia, 1841.

"The machine is drawn by two horses, managed by a boy and usually requires the ground to be first plowed, then by simply elevating and guiding the handles a little, the driver uses it to load itself, for the horses being in motion it turns it in its clevisses and inclining downward, runs under the loose dirt like a plow; the handles being released, the loaded scoop moves upon two iron-shod runners which form the sides and project below the bottom; and finally after reaching the place of deposit, the handles being smartly elevated, the edge of the scoop which is armed with iron, takes hold of the bank, and the horses moving on, it overturns and discharges its load. In this overturned position, with handles resting on the double tree, it returns upside down to the place of excavation, and is there loaded as before. Although for successful scooping the ground usually requires loosening; it is often the case, especially in sandy material, that it is so soft that the scoop, by its armed edges, is able to excavate it, and load itself, without any previous loosening of the earth.

"All this will be rendered so evident to the reader, by an inspection of the annexed isometrical sketch, showing a scoop with its double tree, and single trees, that any further mode of operation seems to be entirely unnecessary.



"The writer pursuing his object of acquiring, from actual experiment a knowledge of the cost of excavating materials and forming embankment upon public roads, early addressed himself to observe the effect produced by scoops, and the results of numerous observations upon scooping earth to horizontal distances of from 30 to 80 feet, and heights of 5 to 15 feet; where the slope was 2 feet base to 1 foot rise, established in a satisfactory manner following data:

1," That average earth (yielding readily to the plow) at mean stages of weather and seasons, a scoop load may be taken at one tenth of a cubic yard measured in excavation.

2," That the time lost in loading, unloading and all other ways per load (except in turning) is, at an average, two thirds of a minute.

3," That in every complete turn, or semicircle, described by the horse, one third minute is lost.

4," That if the mean horizontal distance of transportation of earth in a right line, be added to the extreme height scooped measuring vertically from the bottom of the excavation to the top of the bank, then for every seventy feet of the aggregate distance, one minute will be consumed by the horse in going out and returning.

5," That if the earth be all scooped to one side, as for instance to the low heath-banks of a canal, two turns or a complete circle, will be made by the horses, for every load deposited in the bank.

6; That if the earth be scooped to both sides of a canal, but one team, or a semi circle only, will be described by the horses for each load put in the bank.

"From the fifth and sixth observation, it follows that clear of the time needed to overcome the horizontal haul and vertical height, the constant amount of time lost, will be:

Time lost in loading etc.	=	2/3 minute
" " " turning once	=	1/3 " "
Total	=	1 minute (In Double Scooping)
Time lost in loading etc.	=	2/3 minute
" " " turning twice	=	2/3 " "
Total	=	1 1/3 minute (In Side Scooping)

"Now if the sum of the mean horizontal haul and the extreme height scooped, both in feet, be put = a, the number of hours wrought per day = b, the number of yards excavated and placed in bank per day by each scoop = x, then the general formula to find x in double scooping will be:

$$x = \frac{\left(\frac{60}{\frac{a}{10}+1}\right) b}{10}$$

"Transforming the equation by the rule of algebraic fractions, and substituting for b the average number of hours commonly wrought per day, equal to 10, we are able to reduce the formula for double scooping to

$$x = \frac{4200}{a+70}$$

For side scooping $x = \frac{\left(\frac{60}{\frac{a}{10} + 1\frac{1}{3}}\right) b}{10}$

which, transforming by the rule of algebraic fractions, becomes

$$x = \frac{4200}{a + 93\frac{1}{3}}$$

Now putting the cost per cubic yard of excavation in bank clear of all profits = y, the daily wages of a scoop and driver in cents = c, the cost per cubic yard in cents, of loosening the earth = d, the formula to find y, the cost in cents per yard, either in double or single scooping, will be

$$y = \frac{c}{y} + d$$

The actual number of cubic yards excavated and put in bank by scoops, in several instances having accurately been known by the writer, the correctness of formula (1) and (2) will be tested by these cases.

Example I Double Scooping

In this case, 3600 yards were excavated and put in bank by ninety day's work of scoops, or per scoop per day = 40 cubic yards = x. The mean horizontal haul was 26.5 feet. The extreme height scooped 8 feet. Aggregate distance = 34½ feet = a. Then by formula (1) we have

$$\frac{4200}{a+70} = x \text{ or } \frac{4200}{34.5+70} = \frac{4200}{\frac{209}{2}} = 40.2 \text{ cubic yards} = x$$

Here the calculated and actual days work of the scoops is the same within 0.2 of a cubic yard.

Example II. Single or Side Scooping

"In this case, 5000 cubic yards were excavated and deposited in bank by 176 days of scoops, or scoops per day = 28½ cubic yard = x. The mean horizontal haul was 44 feet, the extreme height scooped 11 feet. Aggregate distance = 55 = a. Then by formula (2) we have: $\frac{4200}{a+93\frac{1}{3}} = x$ or $\frac{4200}{55+93\frac{1}{3}} = \frac{4200}{\frac{445}{3}} = \frac{12600}{445} = 28.3$ cubic yards = x

Hence the difference between real and calculated days of work of a scoop is $\frac{1}{5}$ of a yard.

"Conceiving it to be unnecessary to display at length any more of the examples, we will embody in the following table, the results of actual experiments, and compare them with those calculated by the formula.

1	2	3	4	5	6	7	8	9	10
NUMBER OF EXPERIM	KIND OF SCOOPING	MEAN-HORIZONTAL-HAUL	EXTREME HEIGHT SCOOPED	VALUE OF 4, OR SUM OF 3 AND 4	No. OF CUB. YDS EXC. OR PUT IN BANK	DAYS WORK OF SCOOPS EMPLOYED IN DOING THE WORK STATED IN COLUMN 6	No. OF CUB. YDS. ACTUALLY EXC. PER DAY BY EACH SCOOP	No. OF CUB. YDS. EXC. PER DAY PER SCOOP CALCULATED BY FORMULA I & II	COST PER CUB. YD. OF EXC. CALCULATED BY FORMULA II
1	DOUBLE	26½	8	34½	5000	126	39.7	40.2	7.8
2	DOUBLE	26½	8	34½	3600	90	40.0	40.2	7.8
3	SIDE	44	11	55	5000	176	28.5	28.3	10.7
4	SIDE	36	6	42	5610	181	31.0	31.0	9.9
5	SIDE	40	9	49	852	28½	30.0	29.5	10.3

"In calculating column 10 of the foregoing table, the hire per day of a scoop and driver, has been assumed to be 275 cents; and the cost of loosening, at 1 cent per cubic yard. The near coincidence of the results in columns 8 and 9, shows how closely the calculated number of cubic yards, excavated per day, in each kind of scooping, agrees with the real days work of each scoop, as actually ascertained in excavating 70062 cubic yards of earth; consequently, we may regard the formula which we have deduced, as being sufficiently confirmed to justify a full reliance upon them in practice."

"On the Cost of Embankments of Earth, when made with Carts"*
by Ellwood Morris, Civil Engineer.
[Full abstract]

"Haul ranged from 100 to 1800 feet, formulae based upon and their accuracy tested by application to more than 150 000 cub. yds, so that the formulae can safely be relied upon in practice.

"The carts are drawn by a single horse. The average pace of a horse in carting embankment is a rate of 100 feet of trip or 200 feet lineal per minute. (trip includes both going out and coming back, outward pace a little slower than inward.)

"The earth is classified into three classes: 1st. Gravelly Earth, which is gravel and clay mixed. A medium laborer will load into a cart in ten working hours, ten cubic yards measured in bank. 2d., Loam, which is sand and clay mixed of which a medium laborer will load into a cart in ten working hours twelve cubic yards measured in bank. 3d., Sandy Earth, which includes marly earth, all light, loose and easily handled earth, of which at the above rate fourteen cubic yards can be put in bank. The above earth will measure about 1/9 less after being compacted in the embankment than in its original position in excavation.

"The haul is divided into three classes: 1st. Descending hauling,

*Journal of Franklin Institute, Vol. 2, page 737. Philadelphia, 1841.

carts carry 1/3 of a cubic yard measured in bank. 2d. Level hauling, carts carry 10/35 cubic yards measured in bank. 3d. Ascending hauling, when at the above rate, 1/4 cubic yard is handled. In filling these carts, short hand shovels are usually employed. Gravelly earth is loosened by a pick. Loam is plowed by a good team, sandy earth is easily plowed if it needs it. The expense of loosening varies from 1 to 8 cents per cubic yard. One horse or team can loosen from 750 to 800 cubic yards per day, rating plow and driver at $5.00 per day, will make the cost of loosening vary from 6 mills to 2 cents per cubic yard.

"Time lost in loading, dumping, waiting to load and all other lost time per load is taken at 4 min. Cost of trimming and tossing, at 1 cent per cubic yard.

"Let a = average haul of the embankment in stations of 100 feet each, b = number of hours actually worked per day, c = daily wages of one laborer including all allowance in cents, d = daily wages of one cart including driver and all other expenses in cents, e = cost of loosening the material in cents per cubic yard, x = number of cubic yards measured in bank which can be hauled by each cart per day, to the distance of average haul and there deposited y = the cost in cents of one cubic yard of embankment of the given average haul, clear of all profit to the contractor or person doing the work. Then the general formula representing the number of cartloads to the yard by f, is

$$x = \frac{\left(\frac{60}{\frac{a}{100} + 4}\right) b}{f}$$

To find x substituting for f 3, 3½ & 4 respectively we have:

For Descending hauling $x = \frac{20\,b}{a+4}$

For Level hauling $x = \frac{17\frac{1}{7}\,b}{a+4}$

For Ascending hauling $x = \frac{15\,b}{a+4}$

"To find y: Denoting the number of cubic yards of each class of earth which can be loaded by a medium laborer in a day of ten hours working time, as heretofore stated, by the symbol g, and putting one cent for the cost of trimming and loosening per cubic yard the general formula will be:

$$\frac{c}{g} + \frac{d}{x} + e + 1 = y$$

Substituting for g 10, 12 & 14 respectively we have:

For gravelly earth $y = \frac{c}{10} + \frac{d}{x} + e + 1$

For loam $y = \frac{c}{12} + \frac{d}{x} + e + 1$

For sandy earth $y = \frac{c}{14} + \frac{d}{x} + e + 1$

The table on the following page is a comparison of results between actual experiments and calculations by the above formulae.

No. CUB.YDS. IN BANK	AVERAGE HAUL IN STA. OF 100 FEET EACH	KIND OF HAULING	CLASS OF THE EARTH	ACTUAL COST PER CUB. YD. IN CENTS	COST CALCULATED BY THE FORMULA IN CENTS	DIFFERENCE PER CUB. YD. IN CENTS
28100	6.5	LEVEL	LOAM	20.1	21.1	1
42140	9.0	LEVEL	SANDY-EARTH	21.8	22.0	0.2
23500	6.0	ASCENDING	SANDY-EARTH	22.0	21.6	0.4
36000	9.2	LEVEL	SANDY-EARTH	22.6	22.9	0.3
22075	10.0	LEVEL	LOAM	27.9	28.1	0.2

Discussion of Morris's Results.

These articles when first published gave valuable information on the subject of moving earth, and were formerly frequently recommended by well known engineers, and yet referred to by some. But since the publication of these articles sixty years have past and the implements used have changed materially. In place of the small and clumsey wooden scoop used for short hauls, we find today the modern solid-steel drag or slip scraper. and where carts were used the wheeled scraper with nearly an equal capacity have almost entirely taken their place. Other dirt-hauling machinery, such as graders and steam shovels, have been invented and proven their efficiency by greatly reducing the cost of moving earth.

In some other respects, Mr Morris's results are hardly in keeping with the best modern engineering practice. For example, he implies that a boy can drive the team and fill the scraper. but the drag scraper in ordinary use today is certainly much better constructed and easier filled than the one described by Mr. Morris, and yet an able-bodied man is usually employed to fill the scraper, and sometimes another to dump them: in which case the driver manages the team only. His statement that the scoop was most frequently employed in excavating trunks of canals is true, since at the time of publication of his article, railroad construction was a thing of the future. Its development has done a great

deal to improve the methods of handling earth and lower the cost of its transportation.

Mr. Morris seems to think because his formulas agree with with the tables, that therefor they are correct and general; but a moments consideration will show that the agreement of the formulas with the tables simply prove the correctness of the mathematical work of deducing the formulas, and gives no evidence whatsoever of its general reliability.

Mr. Morris is to be commented for taking note of the fact that vertical distance is an important element in the cost of moving earth; but he is not to be commented for his method of taking account of the vertical element. A foot of vertical is probably 15 to 20 times as expensive as a foot of horizontal distance, and consequently he should have multiplied his vertical distance by such number before adding it to the horizontal distance to obtain the equivalent length of haul.

Part II. Trautwines Results.

Trautwine in his Engineers Pocket-Book devotes several pages to the cost of moving earth. Glancing over these we at once notice the similarity between the methods of Trautwines and Morris, in fact the former seems to include all the data of

of the latter. It must be admitted that several good additions have been made and that Trautwine's results come nearer to the present practice than Morris's. But on the whole the prices are too low and the quantities handled too high. For example anyone having any experience in moving earth knows that it is utterly impossible to handle earth in drag scrapers for 2½ cents a cubic yard, or to move 270 yards in a day - as stated by Trautwine. His quantities moved by wheel scrapers are still more absurd. His table on page 748 gives the quantity of dirt moved 50 feet as 700 yards. It is a well known fact among engineers and contractors that a slip will move more dirt at 50 feet than a wheel scraper, and at 100 feet an equal amount, as the time lost in loading, dumping and turning a wheeled scraper offsets its larger capacity. According to Trautwines tables, at 100 feet the wheeled scraper will handle sixty more yards than the drag scraper, a quantity, which in the writers estimation, will keep an additional team busy for a day.

Part III. Authors Results.

The data in the following discussion were obtained by correspondence and conversation with engineers and contractors, and from the writer's personal experience in earth construction.

The wages for team and driver are taken at $3.00 a day and of a common laborer at $1.00, which are probably a little less than the average for the country over, but are taken in round numbers for greater convenience in substituting other values. Nothing is added for profits because of the uncertainty of this important factor.

The subject will be divided according to means employed in transporting the earth, into work with drag scrapers, wheel scrapers, carts, and wagons.

Drag Scrapers.

Drag scrapers, or slips as they are often called, are made in three sizes known to the trade as No 1, 2, and 3, and having capacities of 5½, 4½ and 3½ cubic feet respectively. Table I page 22, shows the estimate of various engineers and contractors as to the quantity of earth that can be moved at various distances with a drag scraper in a day of ten working hours. Table II page 23, shows the average of the estimates of these engineers and contractors as to the amount of earth moved per trip for different sized slips. Table III page 24, shows the various elements of the cost of moving earth with a drag scraper and also the total cost at various distances.

The cost of loosening is figured on the basis that a three horse plow is worked from five to seven hours a day in loose earth, and that a six horse plow is kept busy all day in hard

ground. The cost of loosening remains the same for hauls of different length, because the number of teams working in an excavation are increased as the distance of haul increases, but the yardage moved per team per day decreases. When no loosening is needed, this item may be left out; but if picks are used for loosening, a proportional increase in the cost of loosening over that in the table should be made. The cost of filling the scrapers is figured under the assumption that one man is employed to fill the scraper. The cost of hauling is based on the number of cubic yards of dirt moved in a day of ten working hours by each team. Dumping and leveling is done by a man hired at $ 1.25 per day.

Some writers assume the carrying capacity of a slip, and also assume the average speed of a team, and deduce from these data the volume of earth moved. But it is obvious that the results obtained by this method can not be reliable. The writer has used the method only to roughly check the values in Table III. Different men will load scrapers more or less full, and each scraper load will vary from 1/3 to the full capacity of the scraper. This item is the main factor in the cost of hauling of earth, and should therefor receive careful attention. The best results are obtained when just enough teams are kept in a gang to keep them constantly moving, and no stop should be made for a scraper that is not filled full at the first trial.

Cellar work cost more than the figures in Table III show, since (1) the loosening must then be done by picks and shovels to obtain sharp corners, (2) the loading is more difficult, and (3) the dirt must be hauled out of the excavation up a steep slope. In all cases where dirt is hauled vertically as well as horizontally, the equivalent horizontal distance is equal to the horizontal distance plus 15 or 20 times the vertical haul.

Wheeled Scrapers.

Wheeled scrapers are made in four sizes known to the trade as No 1. 2. 2½ and 3, having capacities of 9, 12, 14 and 16 cubic feet respectively. Table II, page 25, shows the estimate of various engineers and contractors as to the quantity of earth that can be moved per day with wheeled scrapers at various distances. Table I shows the average amount of earth moved per trip for different sizes of scrapers, as estimated by these engineers and contractors. Table II shows the various elements of the cost of moving earth with wheeled scrapers and also the total cost at various distances. The cost of loosening and dumping is the same as for slip scrapers; in filling an additional team and man is used.

Carts.

The capacity of a cart was taken as ½ of a cubic yard. Table III, page 28, shows the data for arriving at the total cost per cubic yard of moving earth in a cart at various distance. The cost of loosening and dumping is the same as for wheeled scraper

work. The cost of filling is figured under the assumption that in loose earth a man loads 18 cubic yards into a cart in 10 working hours, and in hard ground 10 cubic yards. Five men are assumed to load in one cart. The cost of hauling is based on the number of cubic yards of dirt moved per day per cart as given in Table III.

Wagons

The capacity of a wagon was taken as 1½ cubic yards. Table IIII, page 29, shows the cost per cubic yard of moving earth in a wagon at various distances. The cost of loading, filling, hauling and dumping was figured on the same basis as for carts.

TABLE I.

CUBIC YARDS MOVED WITH A DRAG SCRAPER AS ESTIMATED BY VARIOUS ENGINEERS AND CONTRACTORS IN A DAY OF TEN WORKING HOURS

	DISTANCE OF HAUL	25 ft.			50 ft.			75 ft.			100 ft.			LIMIT OF ECONOMIC HAUL
	NUMBER OF SCRAPER	3	2	1	3	2	1	3	2	1	3	2	1	
AUTHORITY	HAMMEL							50	60	70				75 feet
	SHERMAN											30		100 feet
	SPIRE										35		50	100 feet
	CRAMER			100			90			80			70	150 feet
	JOBST			50			46			43			40	150 feet
	THOMPSON											45		80 feet
	WAGENER		50			46			43			40		100 feet

TABLE II

ACTUAL CAPACITY OF DRAG SCRAPERS IN CUBIC FEET AS ESTIMATED BY VARIOUS ENGINEERS AND CONTRACTORS

AUTHORITY	NUMBER OF SCRAPER		
	3	2	1
CRAMER	3.9	4.5	5.4
JOBST	3.0	4.0	5.0
THOMPSON	3.0	4.0	5.0
WAGENER	4.0	5.0	6.0

TABLE III

COST OF MOVING EARTH WITH DRAG SCRAPERS

Daily Wages: Team and Driver $3.00; Man $1.00 - Results in cents per cubic yard.

DISTANCE OF HAUL	25 ft.		50 ft.		75 ft.		100 ft.		125 ft.		150 ft.	
QUANTITY-MOVED-PER-SLIP PER-DAY	70 cub. yds.		63 cub. yds.		55 cub. yds.		47.5 cub. yds		39 cub. yds.		30 cub. yds	
ITEMS OF EXPENSE	LOOSE EARTH	HARD GROUND	LOOSE EARTH	HARD GROUND	LOOSE EARTH	HARD GROUND	LOOSE EARTH	HARD GROUND	LOOSE EARTH	HARD GROUND	LOOSE EARTH	HARD GROUND
LOOSENING	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0
FILLING SCRAPER	0.3	0.4	0.3	0.4	0.3	0.4	0.3	0.4	0.3	0.4	0.3	0.4
HAULING	4.3	5.5	4.8	6.0	5.5	7.0	6.2	8.0	7.7	9.6	10.0	13.5
LEVELING	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
SUPERINTENDENCE	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
WATER-BOY	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
TOTAL	6.1	7.9	6.6	8.4	7.3	9.4	8.0	10.4	9.5	12.0	11.8	14.9

TABLE IV

CUBIC YARDS MOVED WITH A WHEEL SCRAPER AS ESTIMATED BY VARIOUS ENGINEERS AND CONTRACTORS IN A DAY OF TEN WORKING HOURS

DISTANCE OF HAUL		100 ft.			200 ft.			300 ft.			400 ft.			LIMIT OF ECONOMIC HAUL
NUMBER OF SCRAPER		1	2	3	1	2	3	1	2	3	1	2	3	
AUTHORITY	HAMMEL							45	50	55				1000 ft.
	SHERMAN											30		800 ft.
	SPIRE							45	50	55				900 ft.
	THOMPSON								45					1000 ft.
	CRAMER			70			50			40			30	900 ft.
	WAGENER		40			35			30			25		900 ft.

TABLE V

ACTUAL CAPACITY OF WHEEL SCRAPERS IN CUBIC YARDS AS ESTIMATED BY VARIOUS ENGINEERS AND CONTRACTORS

AUTHORITY	NUMBER OF SCRAPER		
	1	2	3
CRAMER	0.29	0.33	0.50
WAGENER	0.30	0.40	0.50
SPIRE	0.30	0.35	0.50

TABLE VI.

COST OF MOVING EARTH WITH WHEELED SCRAPERS

Cost of Team and Man $3.00; allowance for Wear and Tear $.25 a day

Results in cents per cubic yard.

DISTANCE OF HAUL	100 ft.		200 ft.		300 ft.		400 ft.		600 ft.		800 ft.	
QUANTITY MOVED PER SCRAPER PER DAY	50 cub. yds.		45 cub. yds.		40 cub. yds.		33 cub. yds.		25 cub. yds.		17 cub. yds.	
ITEMS OF EXPENSE	LOOSE EARTH	HARD GROUND	LOOSE EARTH	HARD GROUND	LOOSE EARTH	HARD GROUND	LOOSE EARTH	HARD GROUND	LOOSE EARTH	HARD GROUND	LOOSE EARTH	HARD GROUND
LOOSENING	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0
FILLING SCRAPER	1.2	1.3	1.2	1.3	1.2	1.3	1.2	1.3	1.2	1.3	1.2	1.3
HAULING	6.0	7.5	7.0	8.75	7.5	9.5	9.0	11.0	12.0	15.0	17.7	21.0
DUMPING AND LEVELING	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
SUPERINTENDENCE	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
WEAR AND TEAR	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
WATER-BOY	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
ROADS	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
TOTAL	9.3	11.4	10.3	12.65	10.8	13.4	12.3	14.9	15.3	18.9	21.0	24.9

TABLE VII

COST OF MOVING EARTH WITH CARTS

Cost of Horse and Man $2.00; other labor $1.00

Results in cents per cubic yard

DISTANCE OF HAUL	1000 ft.		1500 ft.		2000 ft.		2500 ft.		3000 ft.		3500 ft.	
QUANTITY MOVED PER CART PER DAY	20 cub. yds		16 2/3 cub. yds		13 1/3 cub. yds		11.4 cub. yds.		10 cub. yds		8.75 cub. yds	
ITEMS OF EXPENSE	LOOSE EARTH	HARD GROUND	LOOSE EARTH	HARD GROUND	LOOSE EARTH	HARD GROUND	LOOSE EARTH	HARD GROUND	LOOSE EARTH	HARD GROUND	LOOSE EARTH	HARD GROUND
LOOSENING	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0
FILLING CARTS	5.5	9.0	5.5	9.0	5.5	9.0	5.5	9.0	5.5	9.0	5.5	9.0
HAULING	9.9	9.9	12.0	12.0	14.8	14.8	17.6	17.6	20.0	20.0	23.0	23.0
DUMPING AND LEVELING	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
SUPERINTENDENCE	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
WEAR AND TEAR	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
WATER-BOY	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
ROADS	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
TOTAL	17.3	21.3	19.4	23.4	22.2	26.2	25.0	29.0	27.4	31.4	30.4	34.4

TABLE VIII.

COST OF MOVING EARTH WITH WAGONS

Cost of Team and Man $3.00 per day, other labor $1.00

Results in cents per cubic yard.

DISTANCE OF HAUL	1000 ft.		1500 ft.		2000 ft.		2500 ft.		3000 ft.		4000 ft.	
QUTITY MOVED - PER WAGON - PER - DAY	45 cub. yds.		37½ cub. yds.		30 cub. yds		25.5 cub. yds		22.5 cub. yds		18 cub. yds.	
ITEMS OF EXPENSE	LOOSE EARTH	HARD GROUND	LOOSE EARTH	HARD GROUND	LOOSE EARTH	HARD GROUND	LOOSE EARTH	HARD GROUND	LOOSE EARTH	HARD GROUND	LOOSE EARTH	HARD GROUND
LOOSENING	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0
FILLING	5.5	9.0	5.5	9.0	5.5	9.0	5.5	9.0	5.5	9.0	5.5	9.0
HAULING	7.0	7.0	8.0	8.0	10.0	10.0	11.8	11.8	13.3	13.3	16.6	16.6
DUMPING AND LEVELING	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
SUPERINTENDENCE	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
WEAR AND TEAR	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
WATER - BOY	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
ROADS	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
TOTAL	14.4	18.4	15.4	19.4	17.4	21.4	19.2	23.2	20.7	24.7	24.0	28.0

Steam Shovel and Train

When the amount of earth to be moved is very large it is sometimes economical to install a steam shovel for loosening and loading the material, and to use cars and locomotives for transporting it. But this and similar methods are so infrequently employed that the writer will not attempt to discuss them.

Graders

The most effective machinery for moving earth under certain conditions is the grader. A machine made primarily for roadbuilding but which is capable of other kinds of work. There are two forms, the scraping grader or ordinary "Road Machine" and the elevating grader or "New Era Grader". The first is too well known to require description here. The second consists of a frame supported upon four wheels carrying a plow which loosens the earth and throws it upon an elevator which carries the material to the center of the road embankment or the spoil banks of the ditch or empties it into a wagon drawn alongside to receive it. This is by far the most economical method of handling earth. However the method is not very common and it is not been possible for the author to procure any data in the time available.

Wheelbarrows

When the amount of earth to be moved is small, wheelbarrows can be economically used. They are often employed in the South on railroad work where a cut ranges from two to five feet and the

dirt is wasted. In the nothern states where labor can not be obtained at such a low price, they are seldom resorted to, as they would not prove economical.